Bulletin of Electrochemistry 8 (6) June 1992, pp 259–261

0256-1654/92/$ 3-50

CORROSION AND RESIDUAL LIFE OF STRUCTURES

S SRINIVASAN, N S RENGSWAMY K BALAKRISHNAN

Central Electrochemical Research Institute, Karaikudi-623 006. INDIA.

[Received: 1992 April: Accepted: 1992 June]

Corrosion in reinforced concrete structures reduces the strength of the structures which in turn reduces their life. The change in the load-deflection characteristics of structural elements is discussed in this paper. The change in the load bearing capacity of the structures due to different rates of corrosion with time is discussed. Effect of corrosion on steel stress both in the case of reinforced cement concrete as well as in the case of prestressed concrete has also been analysed. A seven step procedure for assessing the residual life of structures is proposed.

Key words: Corrosion, residual life, load, deflection stress in steel, load bearing capacity

INTRODUCTION

Deterioration of reinforced concrete structures may be due to any one or both of the following reasons:

(i) Concrete deterioration due to chemical attack, and

(ii) Corrosion of steel embedded in concrete due to chloride attack.

Both the above phenomena can cause loss in strength as well as reduce the residual life of the structrues. Loss in strength may be in terms of loss in load bearing capacity; loss in residual life may result in catastrophic premature failure.

In existing structures, deterioration of residual strength is important from the point of view of determining the loading that it can safely and serviceably sustain. Determination of residual life of the structures is important from the point of view of determining the remaining life of the structure. The latter is a more complicated proposition than the former.

After ascertaining the factors contributing to corrosion in a structure, the extent of corrosion, damage and the course of remedial measures to be taken, it is essential to ascertain the residual strength and residual life of the structures.

Two methods are suggested for the evaluation of strength in an existing concrete structure

(i) The analytical method, and

(ii) The static load test method [1].

ANALYTICAL EVALUATION OF STRUCTURAL ADEQUACY

This comprises theoretical stress analysis of the structure, which should also take into account the details of its members and connections, properties of materials, quality of construction and the condition of deterioration and maintenance. Testing of a structural model, compatible in its behaviour with the existing structures, may sometimes be adopted. Analytical evaluation is recommended when-

(a) sufficient information regarding the section properties of the members and other factors mentioned above are available,

(b) a static load test is impractical, or

(c) a static load test may ensure safety.

Some destructive and nondestructive tests may be conducted to evaluate the various parameters required for analytical evaluation. Destructive tests include the collection of samples and testing. Nondestructive tests include ultrasonic pulse velocity, pulse echo methods, radiographic methods, surface hardness methods, etc. To arrive at a valid judgement of structural adequacy, the theoretical results should be modified to take into account the present and anticipated future condition of the structure as affected by cracking, spalling, rusting, deformation, etc. The structure under investigation may be deemed to possess sufficient strength if in the analytical investigation, the load factors and deflections satisfy the requirements of code specifications [2].

STATIC LOAD TEST

Static load tests may be resorted to only when the analytical method is impractical or otherwise unsatisfactory. This is adopted when the details of the structural elements and materials are not readily available and when the design concept is complex making the structural analysis impractical. Preliminary analysis, need of repairs, magnitude of the test load, instrumentation and scaffolding are the pre-requisites. If the portion of the structure tested shows no visible evidence of failure, the following criteria shall be taken as indication of satisfactory behaviour.

(a) If the measured maximum deflection of a beam, floor, or roof is less than $It^{-2}/20,000\ L$

Where I is the moment of inertia, t is thickness and L is span

(b) If measured maximum deflection of a beam, floor, or roof exceeds $It^{-2}/20000\ L$, recovery within 24 hours after removal of the Deflection test load shall be at least 75% of the maximum deflection for RCC and 80% for PSC.

DETERMINATION OF THE RESIDUAL LIFE

All the design data, qualities if the materials used, their compositions, etc, should be known to determine the residual life of the structure. Lack of data on the above makes one suspect the reliability of assessment of residual life. Progress of corrosion and the associated structural response may not be linear and this limits the extrapolation techniques. Continuous monitoring may not throw some light on the relative deterioration with respect to time.

Load-deflection characteristics of prototype model structures with reinforcement representing the different corrosion rates may also give some useful information.

Figure 1 shows the effect of corrosion on deflection and failure load of a prototype model. Curve A represents the load-deflection behaviour of an uncorroded specimen. Curve B represents that of a moderately corroded specimen and Curve C represents a severely a severely corroded RC specimen. It can be seen from these curves that the load-deflection curve droops down as the corrosion rate increases. This clearly indicates the structural behavioural changes occurring during corrosion process. It can also be seen that for a particular deflection, the load carrying capacity of an uncorroded specimen is higher than that of corroded specimens and that the load carrying capacity of a structural member varies with the quantum of corrosion.

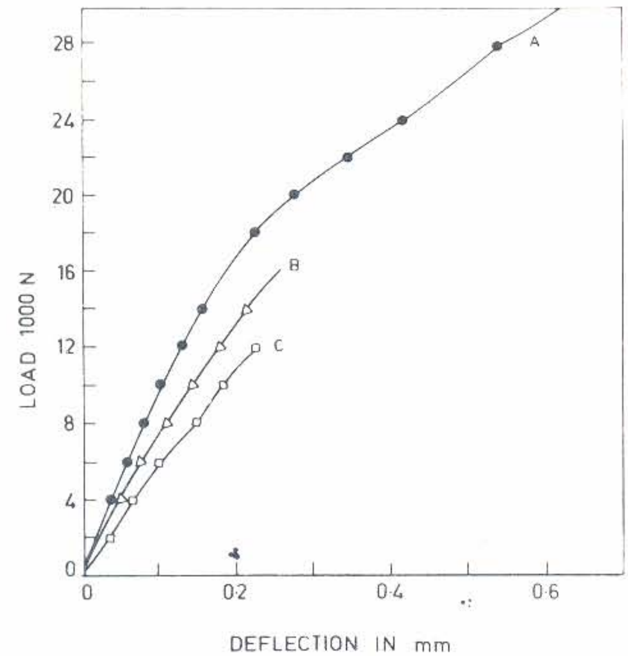

Fig. 1: Effect of corrosion on deflection and failure load

Figure 2 shows the relation between corrosion rate and load bearing capacity. This clearly indicates that the load bearing capacity decreases with increase in corrosion rate. This gives some information about the prediction of the residual life also. Here, it can be seen that it takes 5 years of the reduction of load-bearing capacity by 50% in the case of high corrosion rate and 57 years in the case of low corrosion rate showing that corrosion rate has a bearing on residual strength and life of the structure.

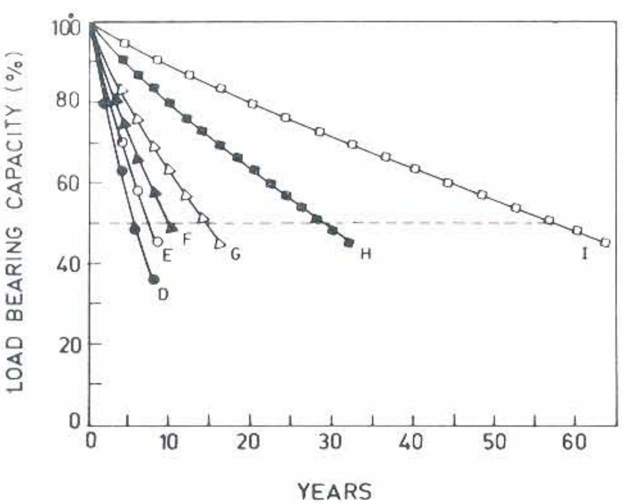

Fig. 2: Effective of corrosion on load bearing capacity (D) 0.5 mmpy (E) 0.4 mmpy (F) 0.3 mmpy (G) 0.2 mmpy (H) 0.1 mmpy (I) 0.05 mmpy

Figure 3 indicates that the stress in steel increases even at the earlier stages when there is high corrosion rate of the order of 0.5 mmpy. It takes longer time for lower corrosion rates. In the case of prestressed concrete structures, corrosion may reduce the residual strength and residual life of the structures at a rate higher than that in the case of reinforced concrete structures. Corrosion leads to loss in diameter of the prestressing steel resulting in loss in prestress. This results in an enormous increase of stress in steel.

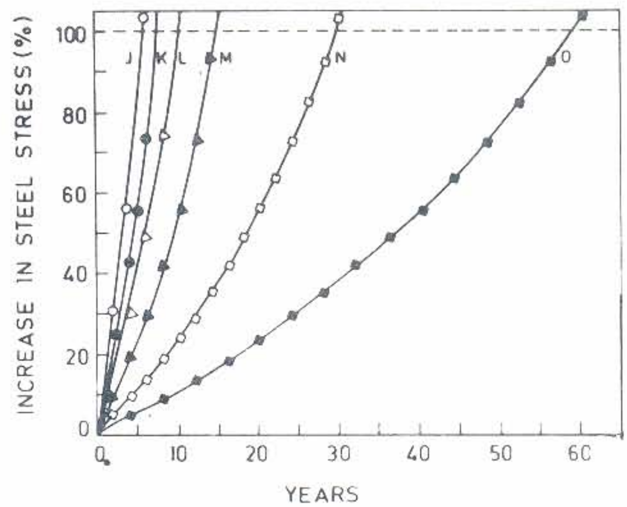

Fig. 3: Effect of corrosion on steel stress (Rebars) (J) 0.5 mmpy (K) 0.4 mmpy (L) 0.3 mmpy (M) 0.2 mmpy (N) 0.1 mmpy (O) 0.05 mmpy

Figure 4 shows the correlation between reduction in diameter of prestressing wire and the corresponding increase in stress values. Reduction in diameter definintely increases the stress in steel. When the diameter reduces from 7 mm to 5 mm due to corrosion, the stress in steel increases from about 75 to 150 kg.mm^{-2}. Yield stress is reached when the diameter reduces to 5.6 mm from 7 mm.

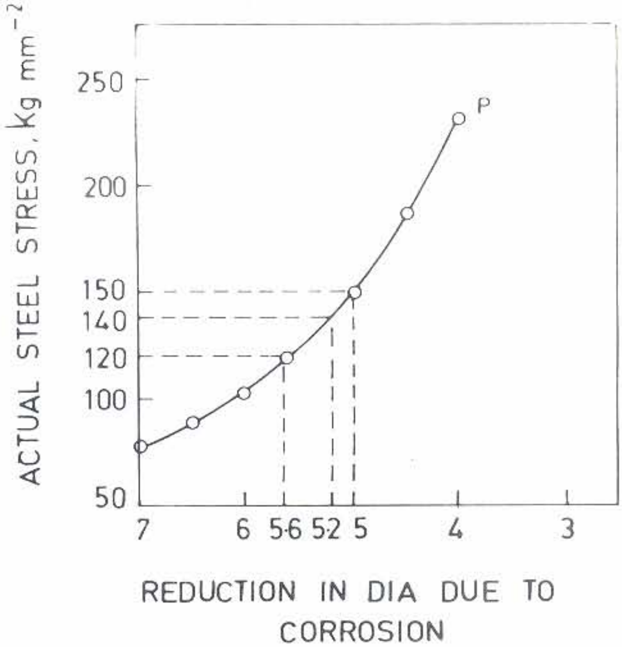

Fig. 4: Effect of corrosion on steel stress (Prestressing steel)

Figure 5 depicts the relation between corrosion rates and loss in load bearing capacity. Curve V shows the reduction in load bearing capacity over year of steel with a corrosion rate of 0.5 mmpy and curve Q represents that for a corrosion rate of 0.05 mmpy. For about 46% reduction in load bearing capacity it takes 5 to 10 years in the case of high corrosion rate. It takes a longer time for lower corrosion rates.

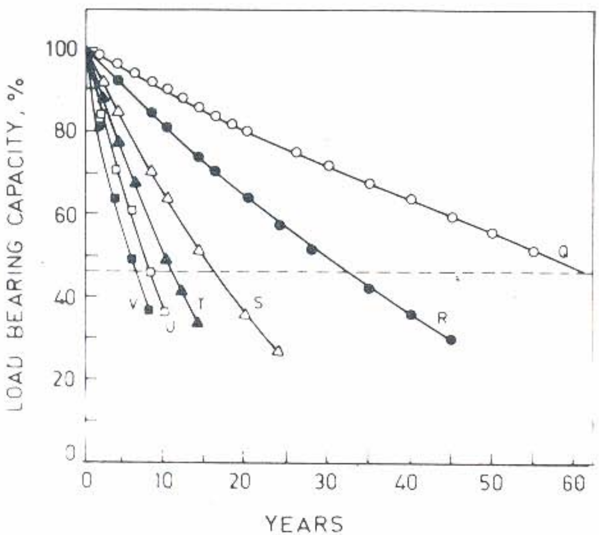

Fig. 5: Loss in load bearing capacity vs years for different corrosion rates.

Figure 6 indicates the correlation between calculated steel strains and measured concrete and steel strains. This indicates that a mathematical simulated model study may throw some light on the assessment of residual life of the structure. The following 7 steps may be useful in determining the residual life of the structure [3].

1. Collection of design data and identification of critical loading conditions and locations.
2. A prototype model study in which para meters like deflections, strains, vibration patterns may be followed. [4].
3. Prototype model with lesser diameter of steel can be studied to assess the change in the above parameter.
4. Qualification of corrosion
5. Assessment of reduction in load bearing capacity

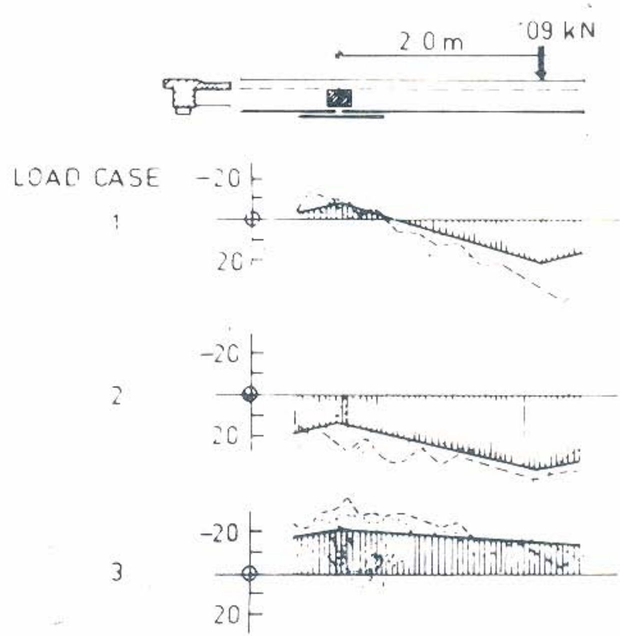

Fig. 6: Development of steel and concrete strains in the glued-steel plate and in the surrounding concrete (in micro-strains)

6. Monitoring of the above over a period.
7. Extrapolation and analysis of the above data.

REFERENCES

1. Recommendations of ACI committee 437
2. *Structural repair, corrosion Damage and Control*—Seminar course manual - SCM 8 (85) ACI
3. *Working paper on condition survey of structures and evaluation of residual life* - CECRI, Karaikudi, India
4. Liu *(Tonye)* (Ed), *Strength evaluation in existing concrete bridges - ACI SP* (88) 1986.